STABILITY OF FIELD EMISSION CURRENT FROM VARIOUS CARBON NANOTUBES FILMS

Benjamin Ulmen, Adam DeConinck, Vijaya Kumar Kayastha, Jiesheng Wang, Yoke Khin Yap*

Department of Physics, Michigan Technological University, Houghton, Michigan 49931

*ykyap@mtu.edu

Keywords: carbon nanotubes, electron field emission, displays, nanotechnology

Abstract

A series of emission current measurements were taken from various types of multiwalled carbon nanotubes (MWCNTs) in order to examine the short-term stability of the substrates under electron field emission (FE) conditions. According to field emission scanning electron microcopy (FESEM), these MWCNT have various tubular lengths, diameters, and growth densities. By referring to these physical properties, we have first optimized their FE properties at vacuum (~1 x 10^{-7} mbar). Then, their current stabilities are compared for samples that are having very similar emission characters i.e. threshold electric field and maximum achievable current density. We found that the MWCNTs films grown by the catalytic thermal chemical vapor deposition (CVD) method exhibited much improved emission stability as compared to MWCNT films grown using the plasma enhanced CVD method. Both types of these MWCNTs films are having a FE threshold of ~1.2 to 1.8 V/μm. As indicated by high-resolution transmission electron microscopy (HRTEM), it was found that the quality of the MWCNTs including the graphitic order and the contents of amorphous carbon, are related to the FE current stability of the MWCNTs.

INTRODUCTION

Carbon nanotubes (CNTs) are well known for their exceptional field emission properties [1, 2]. The multitude of applications for CNT field emitters, including electron microscopy, display devices, vacuum electronics, have caused this to become an exciting and promising area of research. Before this novel material can be made ready for commercial use, stability of the devices under different field emission conditions must be considered. We have studied the degradation of the emission current from multiwalled carbon nanotubes (MWCNTs) grown over a range of conditions and by the techniques of plasma-enhanced chemical vapor deposition (PECVD) and catalytic thermal chemical vapor deposition.

Our PECVD system is a dual-RF plasma system [3, 4]. The nanotubes created by this system have potential for field emission because of the natural vertical alignment caused by the electric field. According to FESEM, these nanotubes tend to be shorter (a few microns) and thick in diameters (50-200nm). We found that the catalytic thermal CVD system can produce nanotubes capable of excellent emission currents at lower voltages [5]. These nanotubes have a higher field enhancement factor caused by their slender diameter (~5 to 10 nm).

The system we have used to make our electron field emission measurements contains several features to optimize the accuracy of the measurements. We have created a "hanging" electrode design to maintain a precise spacing without the use of dielectric material in close proximity to the sample. This minimizes dielectric current leak. The gap between the sample and the electrodes has been precisely measured by a mechanical micrometer and was found to be 315 microns after subtraction of the thickness of the sample. Having a small gap allows us greater accuracy from the relatively smaller applied voltage needed from the power supply. To ensure conductivity through the sample, we have grown all our films on low resistivity (~1ohm-cm) Si substrates with a thin deposited metallic layer to act as a barrier against formation of silicides.

RESULTS AND CONCLUSIONS

We have found that the threshold current, which we have defined as 1μA/cm^2, occurs at a lower electric field for the catalytic thermal CVD grown samples than for the PECVD grown samples, i.e. ~1.2 V/μm and 1.8 V/μm, respectively. Additionally, the short-term stability in the current is much poorer for the PECVD grown samples. Ad indicated by HRTEM, we explain this by the inferior quality of the PECVD nanotubes. The high degree of amorphous carbon accounts for the significant drop in the emission current which initial results suggest is as much as 50% of the initial value over several tens of minutes. The CNT grown by the catalytic thermal CVD method tend to exhibit higher graphitic order and thus emission current shows signs of greater stability, although still decreasing over the course of the experiment.

ACKNOWLEDGEMENT

Y.K.Y. acknowledges supports from the Michigan Tech Research Excellence Fund and the Army Research Office (W911NF-04-1-0029, through the City College of New York).

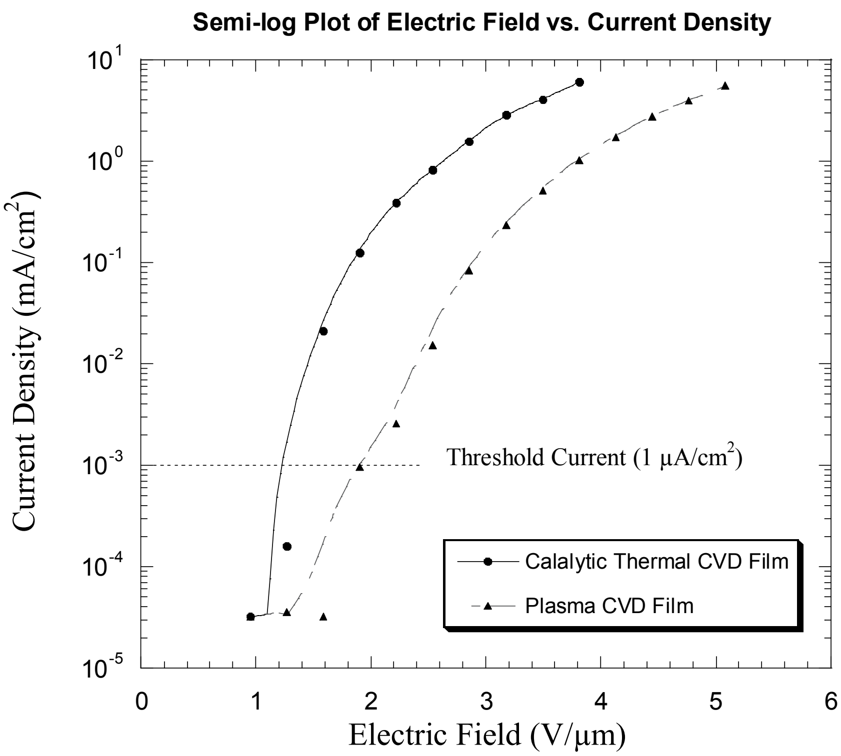

Figure 1. Catalytic thermal CVD films were found to achieve threshold currents at lower electric fields then plasma CVD films. Both types of films are capable of high emission current densities.

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